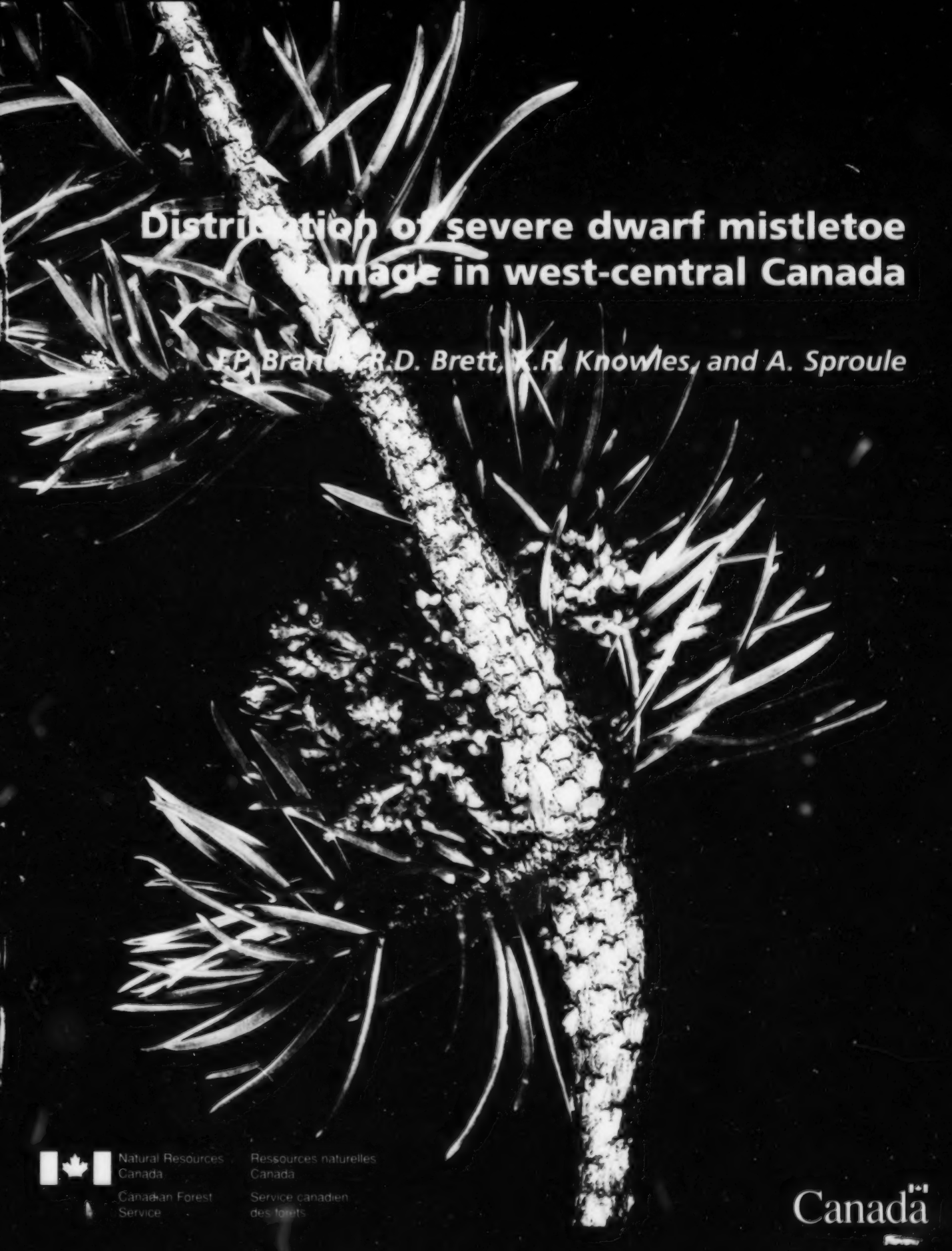

Distribution of severe dwarf mistletoe damage in west-central Canada

P. Brandt, R.D. Brett, K.R. Knowles, and A. Sproule

Natural Resources Canada
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Cover photo:

Aerial shoots of lodgepole pine dwarf mistletoe (*Arceuthobium americanum* Nutt. ex Engelm.) on a lodgepole pine branch.

100-05957/

DISTRIBUTION OF SEVERE DWARF MISTLETOE DAMAGE IN WEST-CENTRAL CANADA

J.P. Brandt, R.D. Brett, K.R. Knowles[1], and A. Sproule[2]

SPECIAL REPORT 13

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1998

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ABSTRACT

The distribution of lodgepole pine and jack pine stands severely damaged by lodgepole pine dwarf mistletoe, *Arceuthobium americanum* Nutt. ex Engelm., is described for Alberta, Saskatchewan, and Manitoba. The distribution of affected stands is based on aerial and ground surveys of jack (*Pinus banksiana* Lamb.) and lodgepole pine (*P. contorta* Dougl. ex Loud. var. *latifolia* Engelm.) forests conducted between 1984 and 1996. Depending on the method of determination, between 455 000 and 585 000 ha of jack pine forests and 80 000–85 000 ha of lodgepole pine forests were severely diseased by dwarf mistletoe. These areas account for about 5% of the total area of pine in the study area. Annual losses due to reductions in growth and tree mortality were estimated at 2 347 000 m^3. Most diseased jack pine stands occurred in the Boreal Plains ecozone, while diseased lodgepole pine stands occurred approximately equally in both the Boreal Plains and the Montane Cordillera ecozones. The report includes maps and a CD-ROM containing an Arc/Info® export-format file of the coverage of pine areas severely damaged by dwarf mistletoe in west-central Canada.

RÉSUMÉ

Le présent rapport décrit la répartition des peuplements de pins tordus latifoliés et de pins gris gravement endommagés par le faux-gui du pin (*Arceuthobium americanum* Nutt. ex Engelm.) en Alberta, en Saskatchewan et au Manitoba. La répartition de ces peuplements a été établie à l'aide de relevés aériens et terrestres effectués de 1984 à 1996 dans les forêts de pins gris (*Pinus banksiana* Lamb.) et de pins tordus latifoliés (*Pinus contorta* Dougl. ex. Loud. var. *latifolia* Engelm.). La superficie gravement infectée par le faux-gui variait de 455 000 à 585 000 hectares dans les forêts de pins gris et de 80 000 à 85 000 hectares dans les forêts de pins tordus latifoliés, selon la méthode de relevé utilisée. Ces superficies représentent quelque 5 % de l'étendue totale des forêts de pins de la région à l'étude. Les pertes annuelles imputables à des réductions de croissance et à la mortalité ont été estimées à 2 347 000 de mètres cubes. La plupart des peuplements infectés de pins gris se trouvaient dans l'écozone des Plaines boréales, tandis que ceux de pins tordus latifoliés étaient répartis à peu près également entre les écozones des Plaines boréales et de la Cordillère montagnarde. Le rapport se compose de cartes des peuplements de pins gravement endommagés par le faux-gui dans le centre-ouest du Canada et d'un CD-ROM à fichier d'exportation Arc/Info®.

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NOTE

The exclusion of certain manufactured products does not necessarily imply disapproval nor does the mention of other products necessarily imply endorsement by Natural Resources Canada.

INTRODUCTION

Lodgepole pine dwarf mistletoe (*Arceuthobium americanum* Nutt. ex Engelm.) is a parasitic, dicotyledonous angiosperm belonging to the family Viscaceae (Barlow 1964). In west-central Canada, this family is represented by two species: *A. americanum* on jack pine (*Pinus banksiana* Lamb.) and lodgepole pine (*P. contorta* Dougl. ex Loud. var. *latifolia* Engelm.); and *A. pusillum* Peck primarily on black spruce (*Picea mariana*), but occasionally on white spruce (*P. glauca*) and jack pine in Manitoba and eastern Saskatchewan.

The biology of this parasite in western Canada has been studied extensively by Dowding (1929), Baranyay (1970), Baranyay and Smith (1972), and Gilbert and Punter (1990, 1991), as well as in the western United States by various workers (Gill 1935; Hawksworth and Wiens 1972, 1996). Lodgepole pine dwarf mistletoe affects its hosts in two ways. First, infections stunt and deform branches, reducing radial and vertical tree growth. Second, as the infections intensify within the host, branch and tree mortality occur. Baranyay and Safranyik (1970) noted growth losses of 18–32% and mortality losses of up to 26% on lodgepole pine in Alberta. Baker et al. (1992) reported volume losses in diseased jack pine stands of 53–70%, which included both growth and mortality losses. Regional estimates of insect and disease impacts indicate that lodgepole pine dwarf mistletoe is second only to decay organisms in its impact on jack and lodgepole pine forests in Alberta, Saskatchewan, and Manitoba (Brandt 1995).

Hawksworth and Wiens (1996) reported the distribution of the mistletoe in western North America as far east as the east side of Lake Winnipeg in Manitoba, northwest to Lake Athabasca in Alberta and Saskatchewan, west to British Columbia, and south to southern California and Colorado (Fig. 1). Their report of the disease's distribution in Canada was based primarily on work conducted by the former Forest Insect and Disease Survey (FIDS) group of the Canadian Forest Service (CFS) and its predecessor agencies, and through the group's collaboration with its provincial counterparts. The eastern maximal distribution of *Arceuthobium americanum* was detected in Ontario in 1969 near Lac Seul in a 400-ha jack pine stand (Sippell et al. 1970, 1971). This stand was destroyed by fire in 1976 and the mistletoe is now considered locally extinct in Ontario (Myren and Gross 1977). Subsequent annual surveys conducted in northwestern Ontario have failed to detect the parasitic plant.

Much of the work conducted by the FIDS group in west-central Canada during the period 1951–1993 concentrated on making collections for the herbarium now maintained at the Northern Forestry Centre in Edmonton, Alberta (herbarium designation CFB). (This collection also contains specimens formerly retained at the CFS's herbarium in Winnipeg, which was designated WINF and was closed in 1970.) This information provided the basis for planning the current study, the primary objective of which is to delineate specific areas of jack and lodgepole pine stands severely affected by *A. americanum* throughout west-central Canada.

Various techniques have been used over the years to estimate the area of forests affected by dwarf mistletoes. Dooling (1978) and Merrill et al. (1985) described techniques that combined roadside reconnaissance with permanent sample-plot assessments. Muir and Robins (1973) developed a technique in which aerial photographs were used to quantify the impacts of *A. americanum* on jack pine. Robins (1972) developed an aerial survey technique in which trained observers used an audio event recorder, an aircraft flying along predetermined flight lines, and forest inventory maps to record the disease's presence. Because dwarf mistletoe on jack and lodgepole pine is clearly visible from an aircraft, and because of recent developments in global positioning technologies, aerial surveys by trained observers flying in aircraft were used as the primary method to obtain the information presented in this study.

METHODS

Preliminary planning for this study involved examining several sources of information. First, spatially related point data on *A. americanum* infections were plotted (Fig. 2). Next, existing maps of infestations, on paper or in digital format, were studied to avoid any duplication of mapping. In

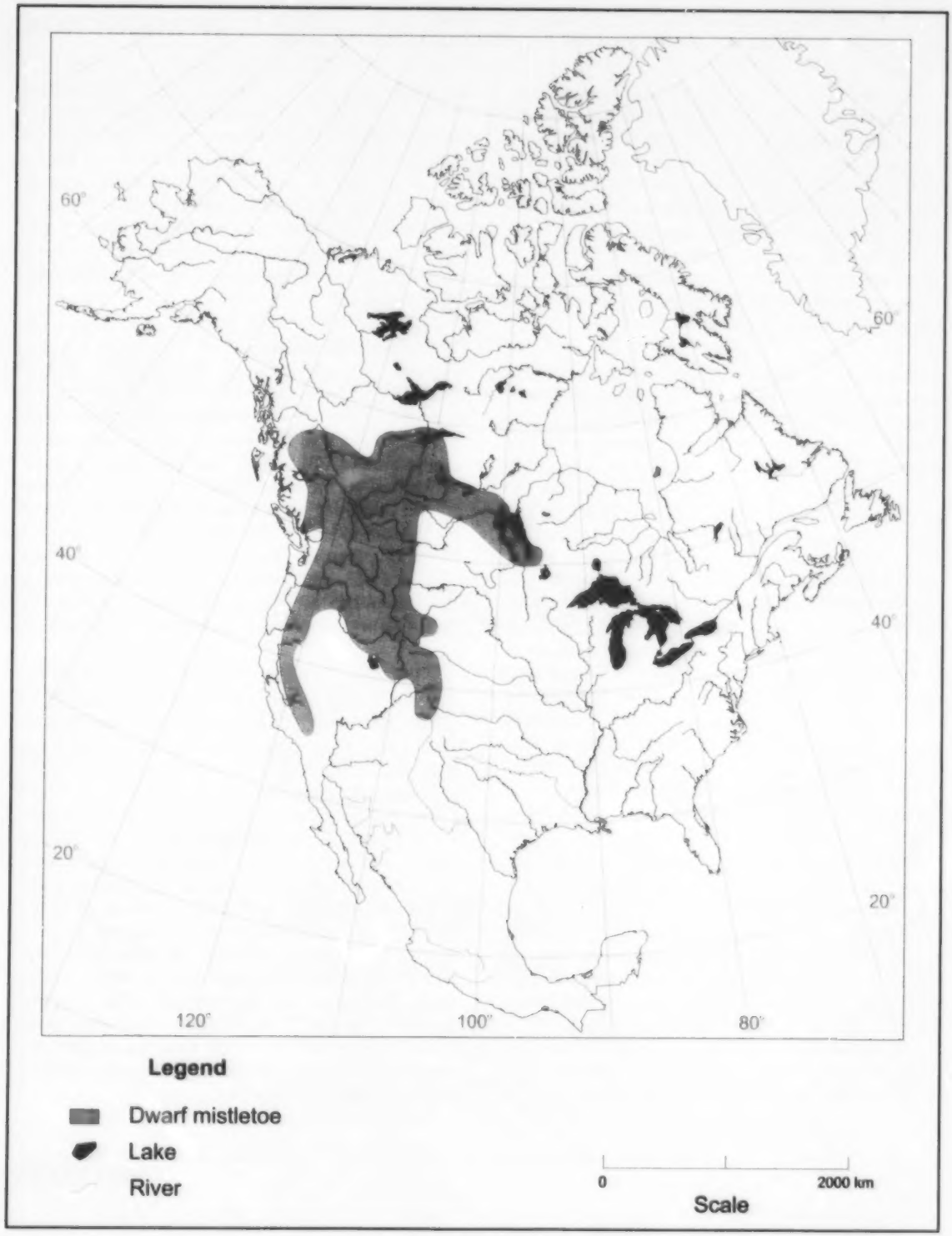

Figure 1. The general distribution of dwarf mistletoe, *Arceuthobium americanum*, in North America. (Hawksworth and Wiens 1996.)

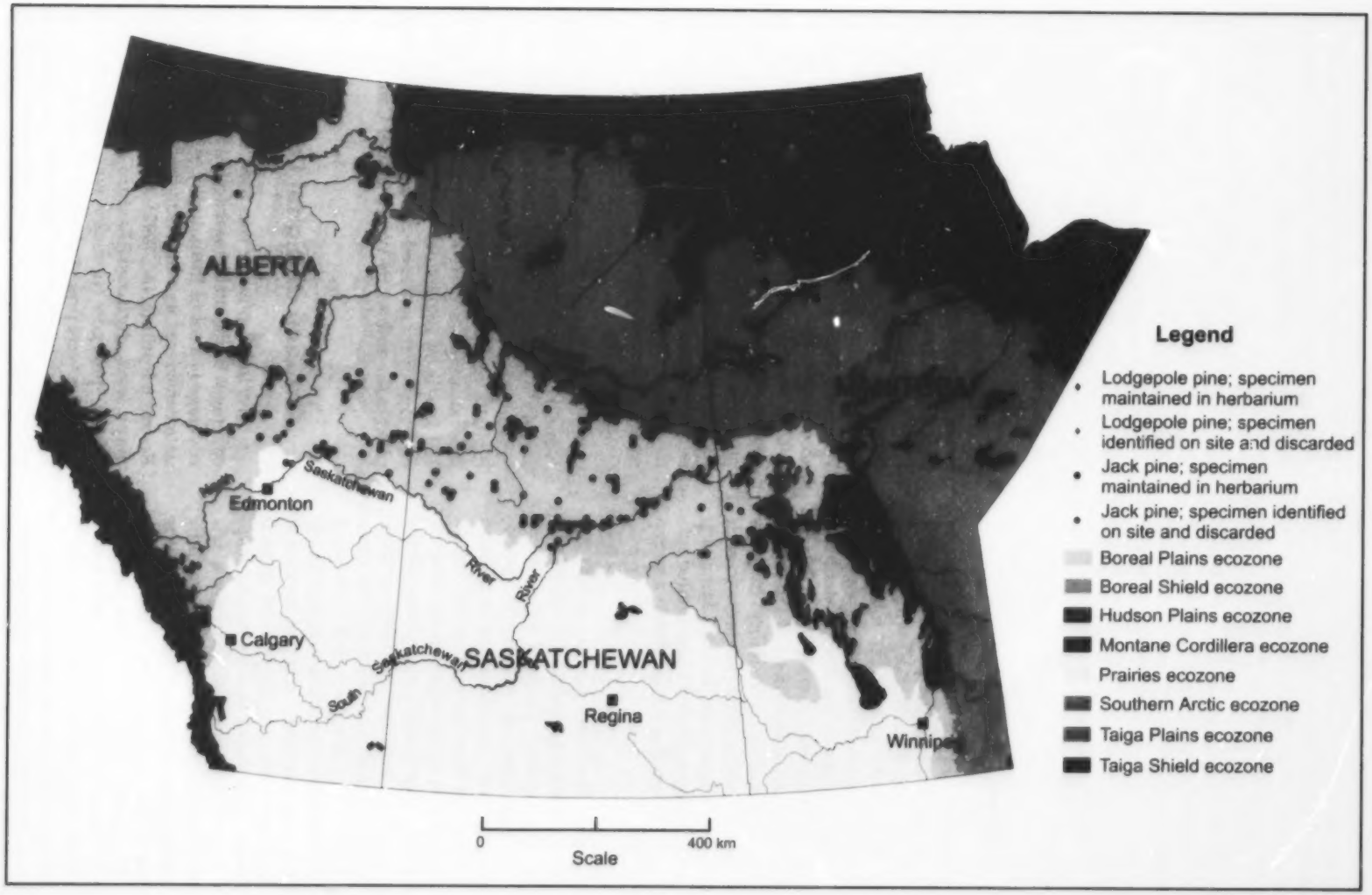

Figure 2. Locations where dwarf mistletoe was collected on jack and lodgepole pine trees by Forest Insect and Disease Survey staff between 1952 and 1993. Specimens from specified locations are maintained in the mycological herbarium (CFB) at the Canadian Forest Service's Northern Forestry Centre in Edmonton, Alberta.

Alberta, some areas of diseased lodgepole pine were mapped in southwestern Alberta by the Alberta Land and Forest Service between 1984 and 1987. In Manitoba, Manitoba Natural Resources mapped most of the severely diseased jack pine stands in the province between 1986 and 1989 (Baker et al. 1992). In Saskatchewan, Weyerhaeuser Canada Ltd. surveyed jack pine stands located within its forest management license area in 1996. Finally, where available, forest inventory information was examined to prioritize locations of potential dwarf mistletoe hosts for subsequent aerial surveys.

Aerial Surveys

Lodgepole pine dwarf mistletoe aerial surveys were conducted throughout the prairie provinces between 1994 and 1996 (Fig. 3). Fixed-wing aircraft were mostly used for the surveys, but rotary-wing aircraft were used in some of the mountainous areas along the eastern slopes of the Rocky Mountain range in Alberta. Fixed-wing aircraft flew at speeds of up to 200 km/h and at elevations of 150–300 m aboveground, depending on visibility. In areas where host stands were in close proximity to each other, parallel flight lines were flown 3 km apart. Along the eastern slopes where valleys limited survey design, one or two flight lines within a valley was the standard.

As the aircraft flew over forests, trained observers sketched diseased areas on 1:250 000-scale maps. Only areas severely diseased by *A. americanum* were delineated on the sketch maps. Severely diseased areas were defined as infested areas containing mistletoe-caused tree and branch mortality and/or trees with many green brooms. These infestations were easily mapped because the red foliage on dead trees and branches, or gray, dead stems and branches, contrasted with the green of healthy foliage on other trees and understory vegetation. Infestations containing trees with many green brooms were also easily mapped because of dramatic differences between the textural appearance of diseased stands and healthy stands. Mapping areas in which trees contained only a few green brooms was difficult because there was little contrast between the diseased growth and the normal foliage, both in terms of color and texture. Consequently, young stands with mistletoe were not mapped because infestations in these stands were not visible from the air. Also, symptoms of mistletoe infection are more severe and prominent on jack pine as opposed to lodgepole pine and, as a result, affected jack pine is easier to map from the air. Most of the aircraft used were equipped with a global positioning system (GPS), which allowed for precise positioning of diseased stands.

The Alberta Land and Forest Service surveyed the foothills along the eastern slopes of the Rocky Mountains from Rocky Mountain House south to Blairmore between 1984 and 1987. Mistletoe-infected lodgepole pine stands were mapped from ground and aerial surveys at scales of 1:15 000 and 1:50 000. Much of this information was subsequently transferred to digital format by Sunpine Forest Products Ltd. and supplied to the authors for this publication.

The survey conducted by Manitoba Natural Resources between 1986 and 1989 (Baker et al. 1992) covered the majority of jack pine stands from Flin Flon southeast throughout the interlake region between Lake Winnipeg and Cedar Lake, and the Belair area on the southeastern shore of Lake Winnipeg. Diseased jack pine stands were mapped according to the procedure described by Robins (1972). Basically, this procedure involved orally describing mistletoe-infected pine stands along predetermined flight lines using an audio event recorder within the aircraft. This information was interpreted and transferred to 1:15 840 forest inventory maps. A global positioning system was not used for these surveys.

In 1996, Saskatchewan Timberlands, Weyerhaeuser Canada Ltd., conducted an aerial survey of stands infected with *A. americanum* in central Saskatchewan. Dwarf mistletoe infestations were digitally mapped using GPS technology. Aircraft flew at altitudes of 150–200 m and airspeeds of 120 km/h on flight lines 1.6 km apart. A digital coverage of the mapped diseased areas was supplied to the authors by Weyerhaeuser Canada Ltd.

Creation of Digital Coverage

Arc/Info® software was used to create digital coverages of the mistletoe-infested areas. A digital coverage is a set of thematically associated spatial data considered as a unit (Environmental Systems Research Institute, Inc. 1992). A total of 272 sketch-maps were digitized. Feature attributes were added, polygon topology was built, and the coverages were projected into the Lambert Conformal Conic projection (see Appendix 1 for projection parameters).

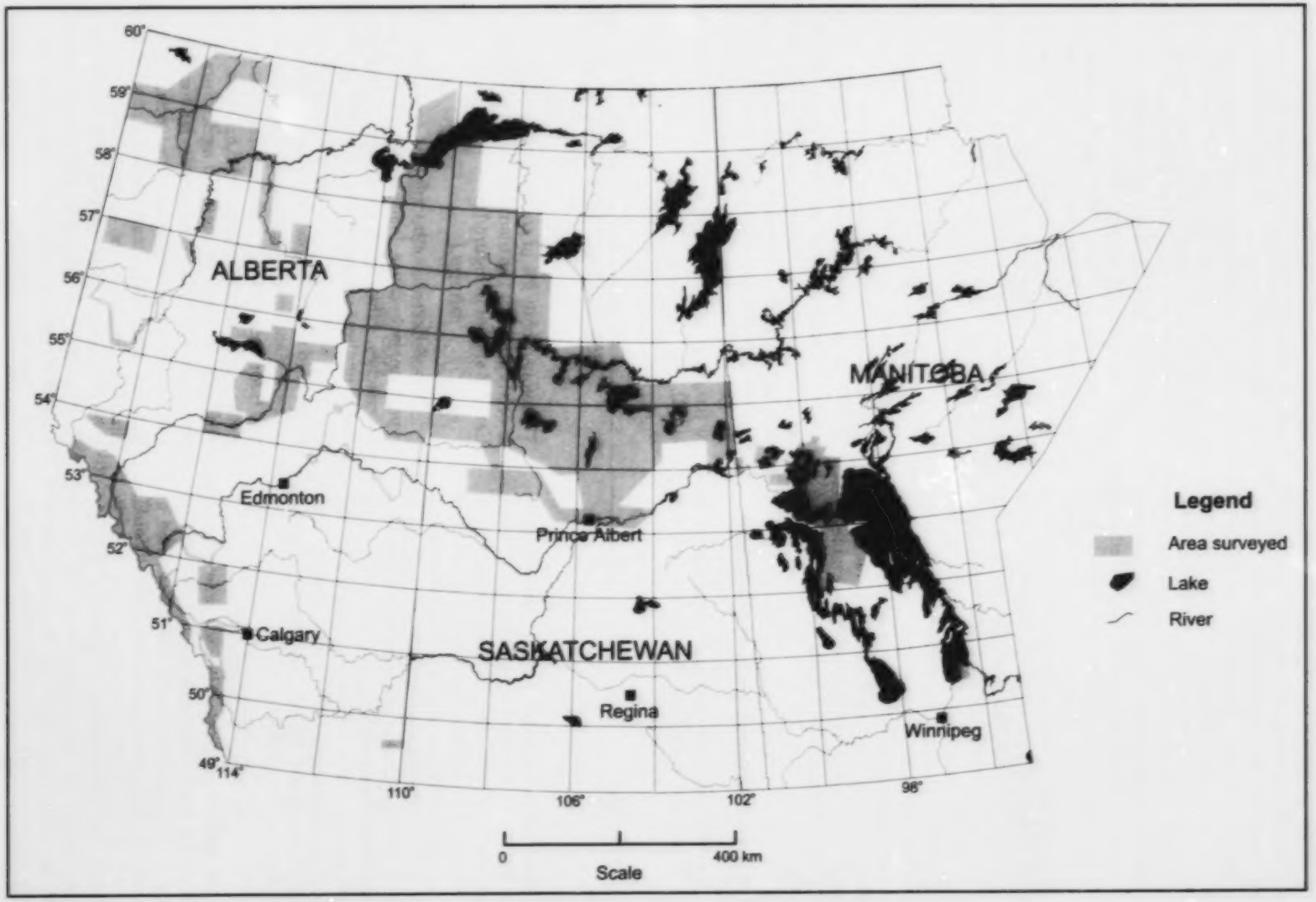

Figure 3. Areas surveyed for dwarf mistletoe on its two principal hosts: jack and lodgepole pine.

In order to merge the digitized sketch-map coverages with the coverages supplied by Sunpine Forest Products Ltd. and Weyerhaeuser Canada Ltd., the two industry coverages were imported into the Arc/Info® coverage format. Feature attributes were then edited, the coverages were re-projected, unwanted features were removed, and topology was re-built. Once these coverages were standardized, they were appended and rebuilt to create the distribution of lodgepole pine and jack pine stands severely affected by dwarf mistletoe in the study area. Finally, with the regional coverage built, two INFO® metadata files were added. One file describes the origin of the coverage, organizational contacts, attributes, topology, projection, acknowledgments, liability, and use-constraint information for the entire coverage. The second file describes data-entry, survey, and map-source information for each feature within the coverage. The feature-based metadata file can be linked to the coverage's polygon attribute table and used in the spatial analysis of the coverage.

Area and Impact Determinations

Two methods were used to determine infested areas of jack and lodgepole pine stands. The first method involved summing the diseased areas using the area of each polygon in the digital coverage. The second method involved several steps. First, the mistletoe coverage was overlaid in the GIS with forest inventory data from the Canada Forest Inventory (CanFI; these data currently reside at the Pacific Forestry Centre in Victoria, British Columbia). Data within CanFI are grouped into cells, with each cell geographically referenced to an area covering 10 × 10 km (Lowe et al. 1994). Eligible areas were then extracted and summed from each inventory cell according to the percentage of the cell that was infested, the percentage of the cell that contained the host tree species, and the area of the host tree species.

Estimation of losses from mistletoe due to growth reductions and tree mortality were determined based on the methods applied by Brandt (1995). Dwarf mistletoe depletion factors applied against infested areas of lodgepole pine were 38% for growth loss and 2.4% for mortality. The depletion factors applied against infested areas of jack pine were 40% for growth loss and 3.0% for mortality. These depletion factors were based on the work of Baranyay and Safranyik (1970) and Baker et al. (1992).

RESULTS AND DISCUSSION

Dwarf mistletoe occurs east of Lake Winnipeg near Belair in Manitoba, northwest to Lake Athabasca in Alberta and Saskatchewan, west to the Alberta–British Columbia border, and south to the Cypress Hills in Alberta and Saskatchewan (Figs. 4–15. Please note: small polygons [<35 ha in size] are not represented on these figures, but they are represented on the digital coverage). This distribution covers five ecozones as described by the Ecological Stratification Working Group (1995): Boreal Plains, Boreal Shield, Taiga Shield, Prairies, and Montane Cordillera.

The areas of polygons with jack pine severely diseased by dwarf mistletoe totaled 585 000 ha (Table 1). If infestation counts are constrained to only suitable host types as determined by the CanFI, then 455 000 ha of jack pine forests were severely diseased. The corresponding values for severely diseased lodgepole pine forest were 85 000 ha and 80 000 ha, respectively. The total estimated area of pine in the study area was 12 853 000 ha (Table 2). Therefore, about 5% of the total area of pine was severely affected. The distribution of pine based on CanFI is shown in Figure 16.

Two different methodologies were used to report areas because inaccuracies exist in both approaches. When areas are sketch-mapped onto maps, nonhost stands might be included in the polygons sketched by the observer. These small errors tend to overestimate the affected area and of course depend on the scale of the map. Forest inventory information also contains several inaccuracies. Areas might not be inventoried (i.e., parks, transition areas between forested and agricultural land, or remote northern, noncommercial forests), or areas might have burnt or been harvested since the last inventory. Also, dwarf mistletoe can virtually eliminate suitable hosts, leading forest inventory staff to classify a site as a nonhost forest type. Further, area determinations differ when different projections are used to project coverages within a GIS. The areas reported here are based on the

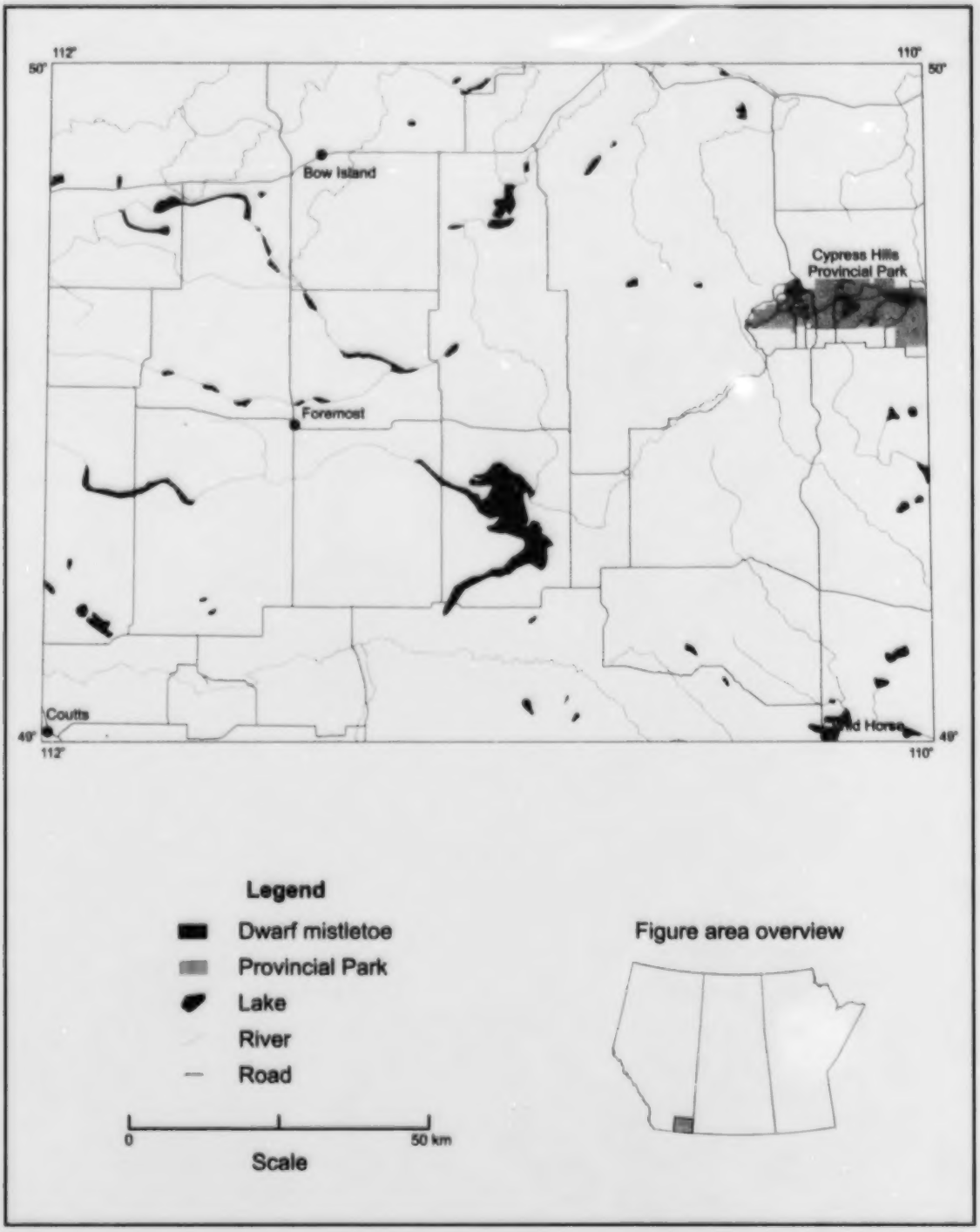

Figure 4. Areas of pine forests severely diseased by dwarf mistletoe in southeastern Alberta bounded by lat. 49°N to lat. 50°N and long. 110°W to long. 112°W. Severely diseased areas are defined as infested areas containing mistletoe-caused tree and branch mortality or trees with many green brooms.

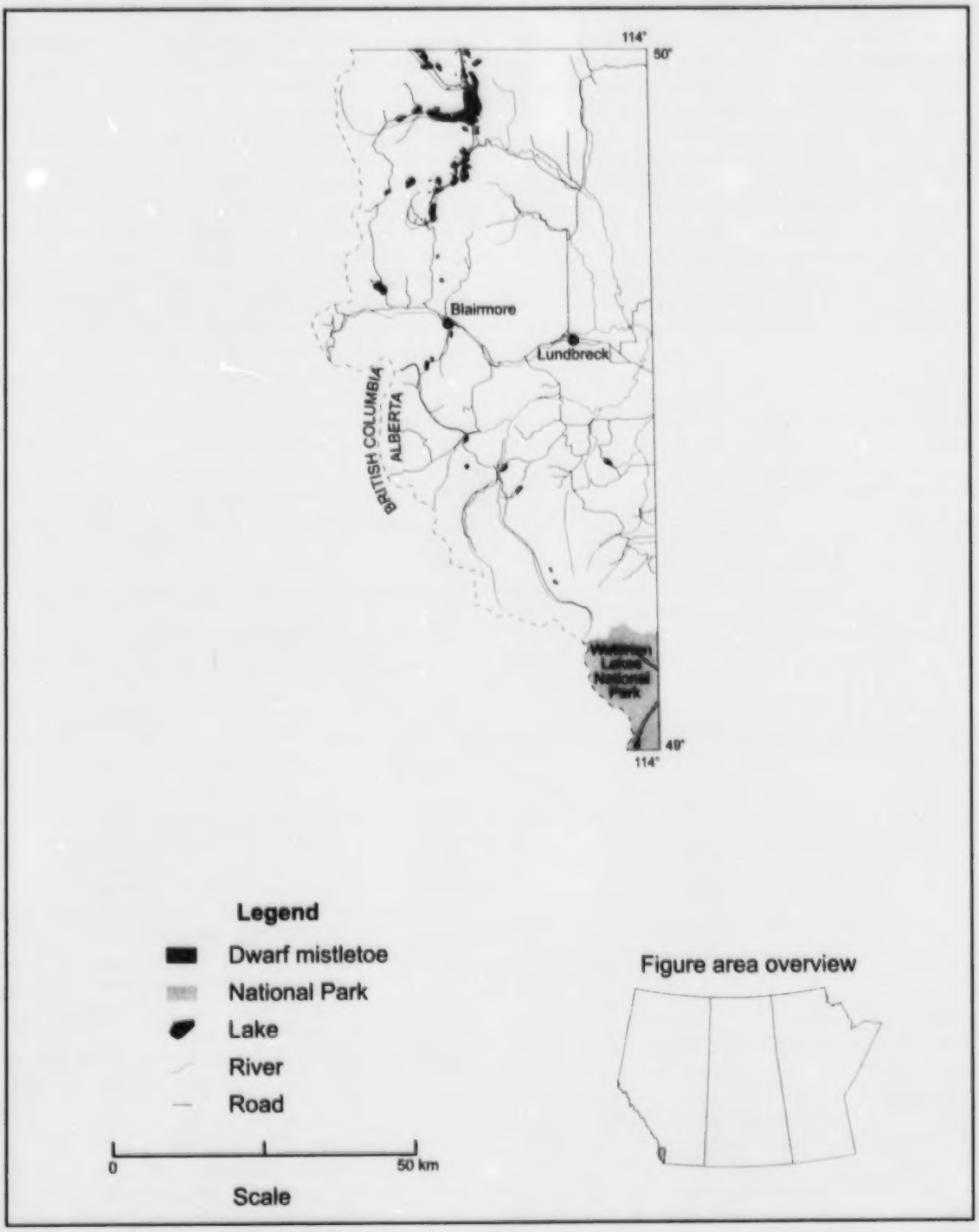

Figure 5. Areas of pine forests severely diseased by dwarf mistletoe in southwestern Alberta bounded by lat. 49°N to lat. 50°N and long. 114°W to the Alberta–British Columbia border. Severely diseased areas are defined as infested areas containing mistletoe-caused tree and branch mortality or trees with many green brooms.

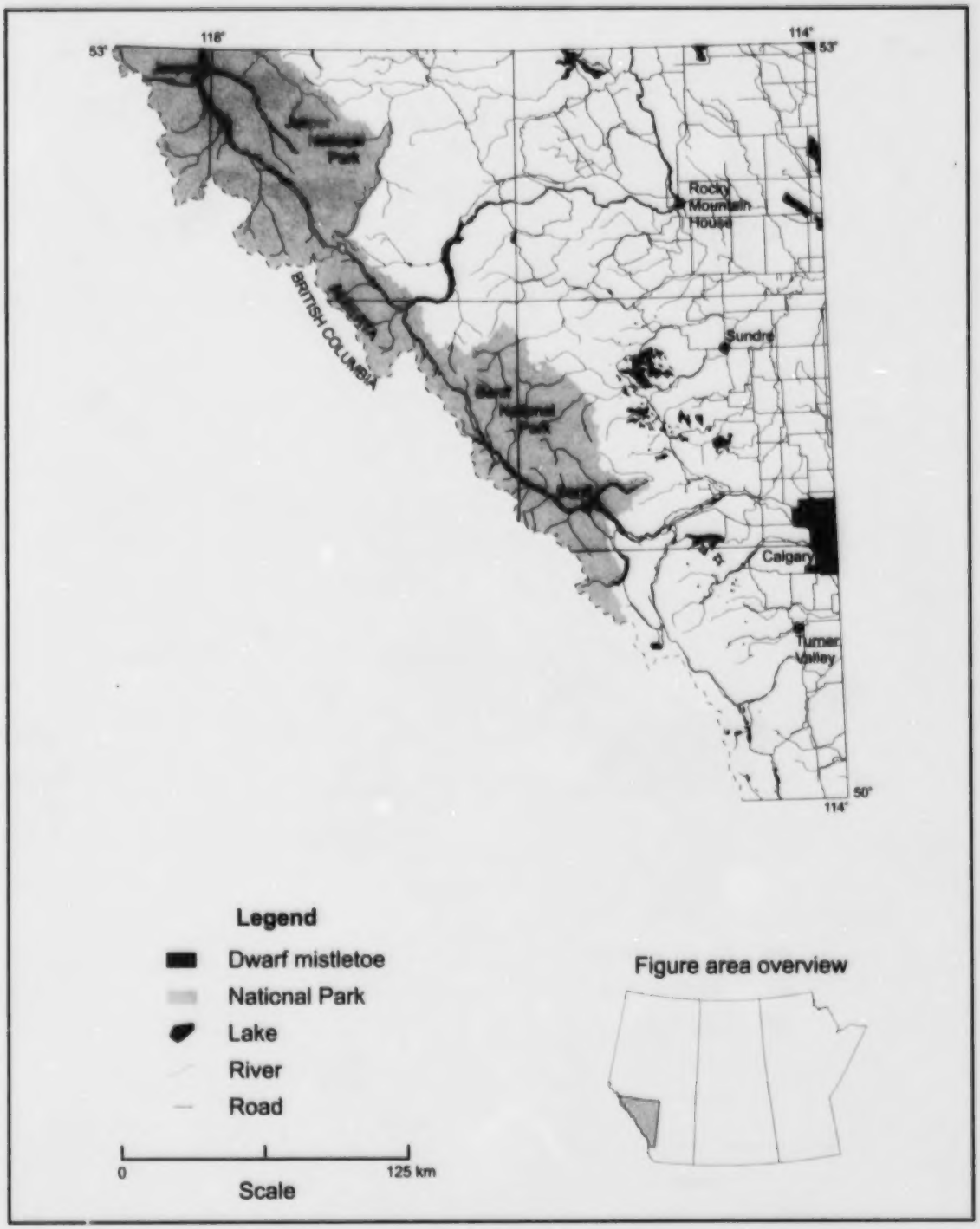

Figure 6. Areas of pine forests severely diseased by dwarf mistletoe in southwestern Alberta bounded by lat. 50°N to lat. 53°N and long. 114°W to the Alberta–British Columbia border. Severely diseased areas are defined as infested areas containing mistletoe-caused tree and branch mortality or trees with many green brooms.

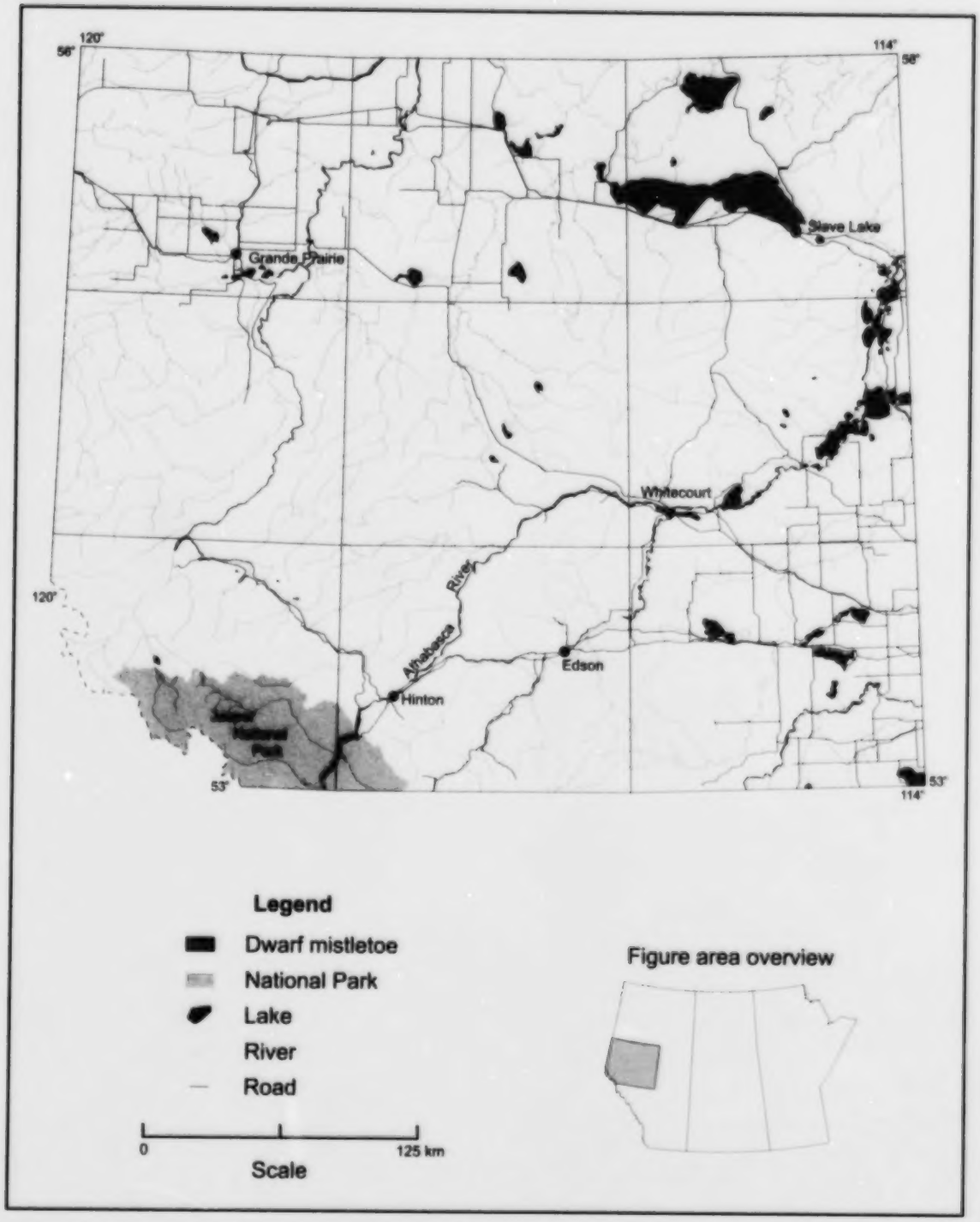

Figure 7. **Areas of pine forests severely diseased by dwarf mistletoe in west-central Alberta bounded by lat. 53°N to lat. 56°N and long. 114°W to long. 120°W and the Alberta–British Columbia border.** Severely diseased areas are defined as infested areas containing mistletoe-caused tree and branch mortality or trees with many green brooms.

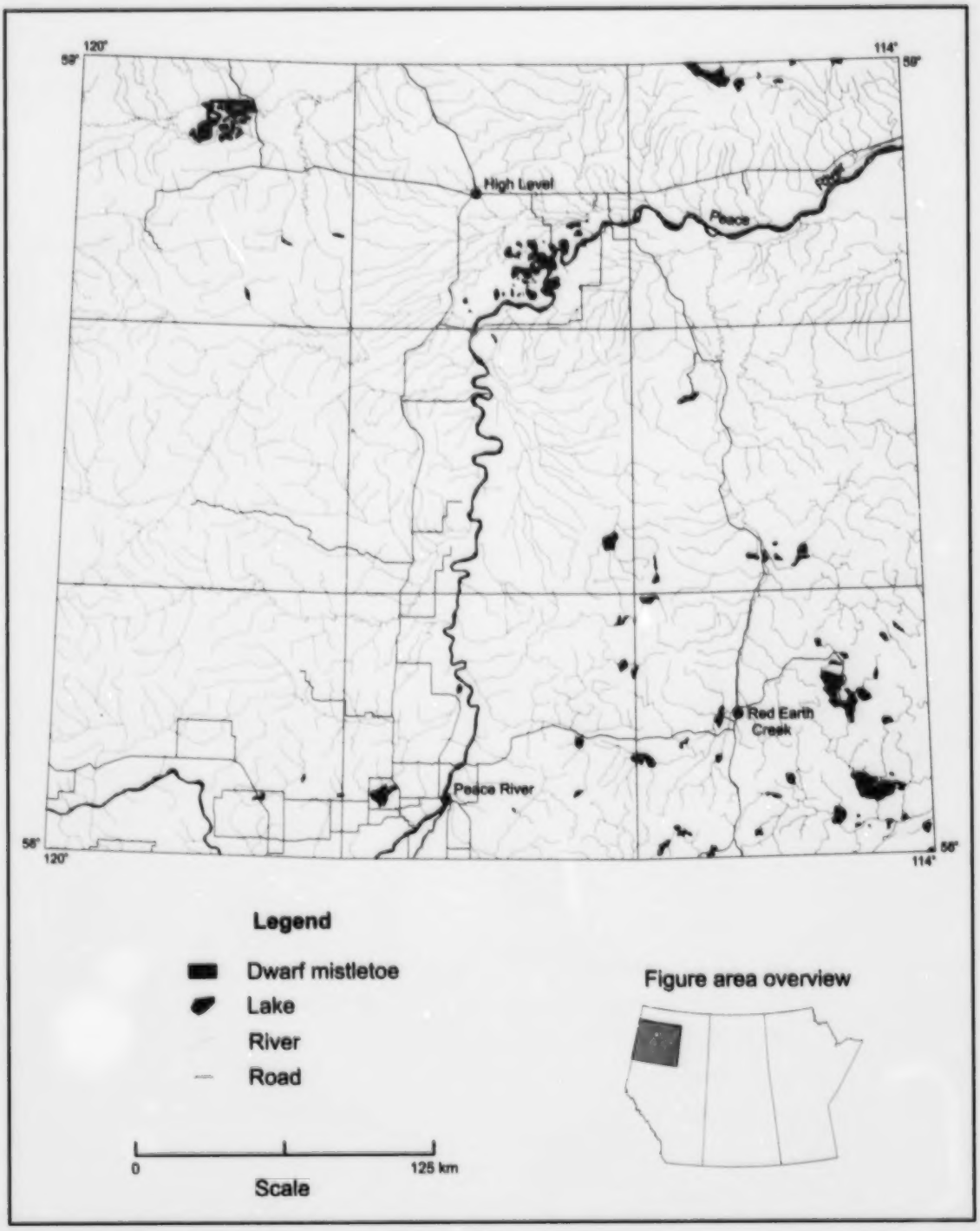

Figure 8. Areas of pine forests severely diseased by dwarf mistletoe in northwestern Alberta bounded by lat. 56°N to lat. 59°N and long. 114°W to long. 120°W. Severely diseased areas are defined as infested areas containing mistletoe-caused tree and branch mortality or trees with many green brooms.

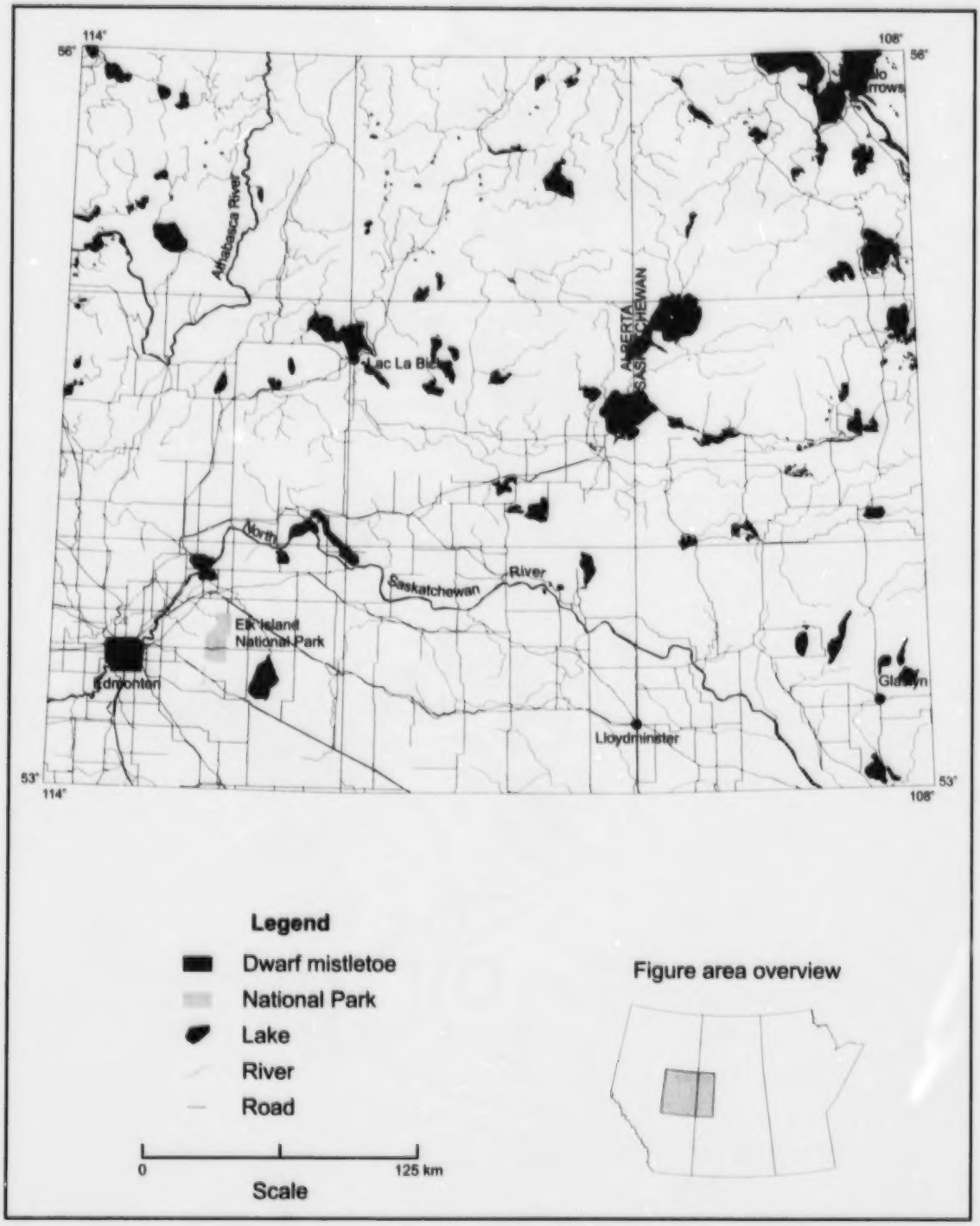

Figure 9. Areas of pine forests severely diseased by dwarf mistletoe in east-central Alberta and west-central Saskatchewan bounded by lat. 53°N to lat. 56°N and long. 108°W to long. 114°W. Severely diseased areas are defined as infested areas containing mistletoe-caused tree and branch mortality or trees with many green brooms.

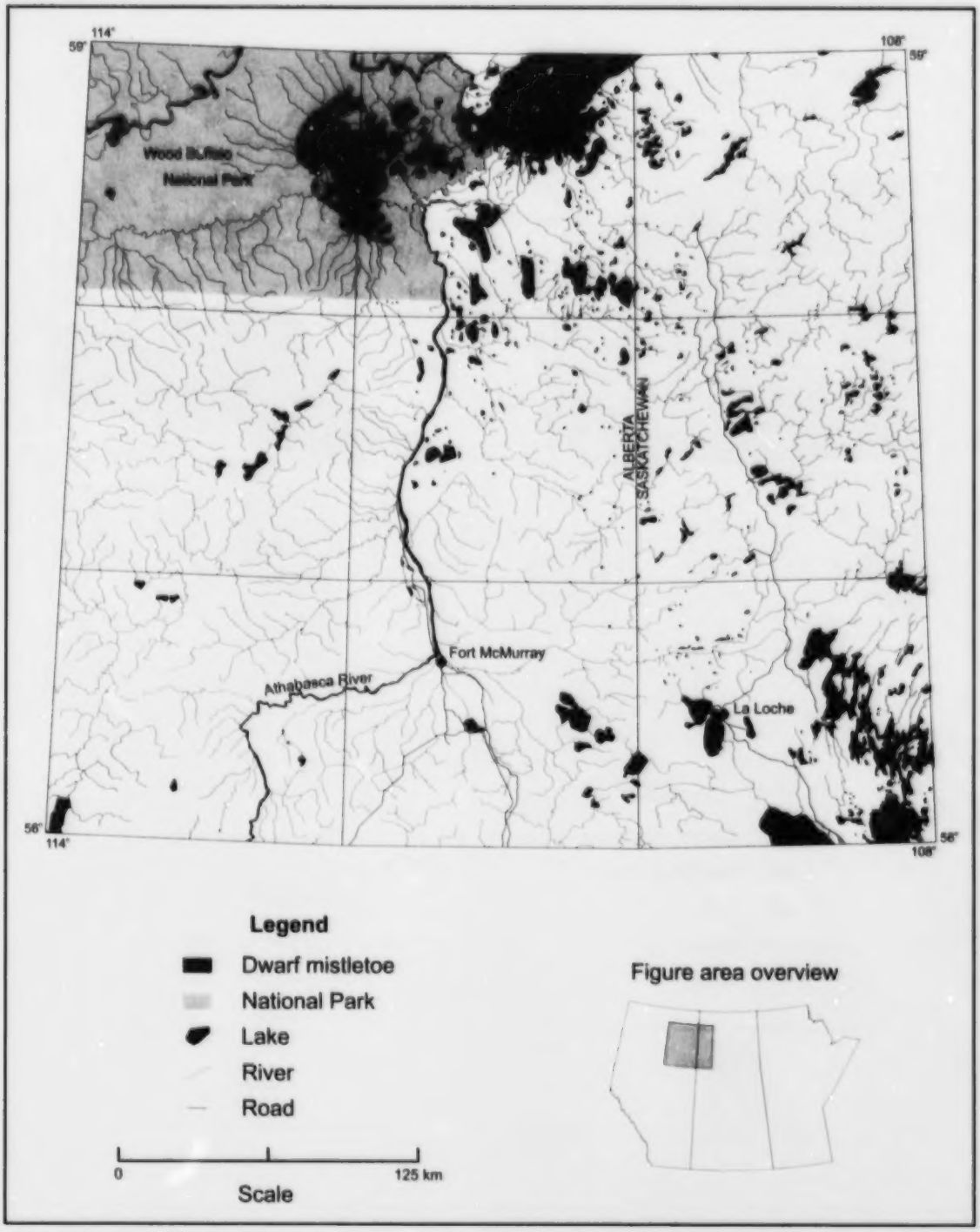

Figure 10. Areas of pine forests severely diseased dwarf mistletoe in northeastern Alberta and northwestern Saskatchewan bounded by lat. 56°N to lat. 59°N and long. 108°W to long. 114°W. Severely diseased areas are defined as infested areas containing mistletoe-caused tree and branch mortality or trees with many green brooms.

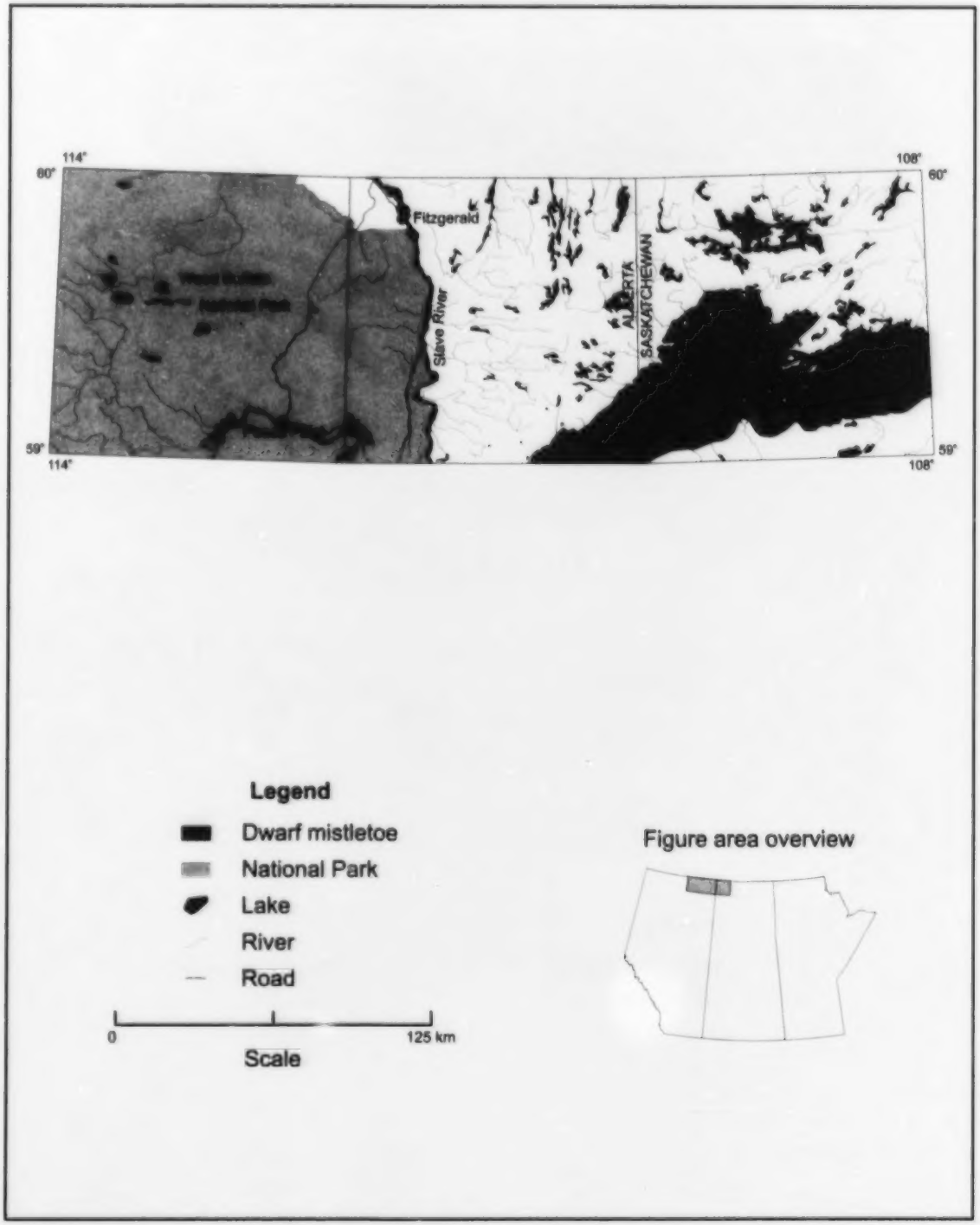

Figure 11. Areas of pine forests severely diseased by dwarf mistletoe in northeastern Alberta and northwestern Saskatchewan bounded by lat. 59°N to lat. 60°N and long. 108°W to long. 114°W. Severely diseased areas are defined as infested areas containing mistletoe-caused tree and branch mortality or trees with many green brooms.

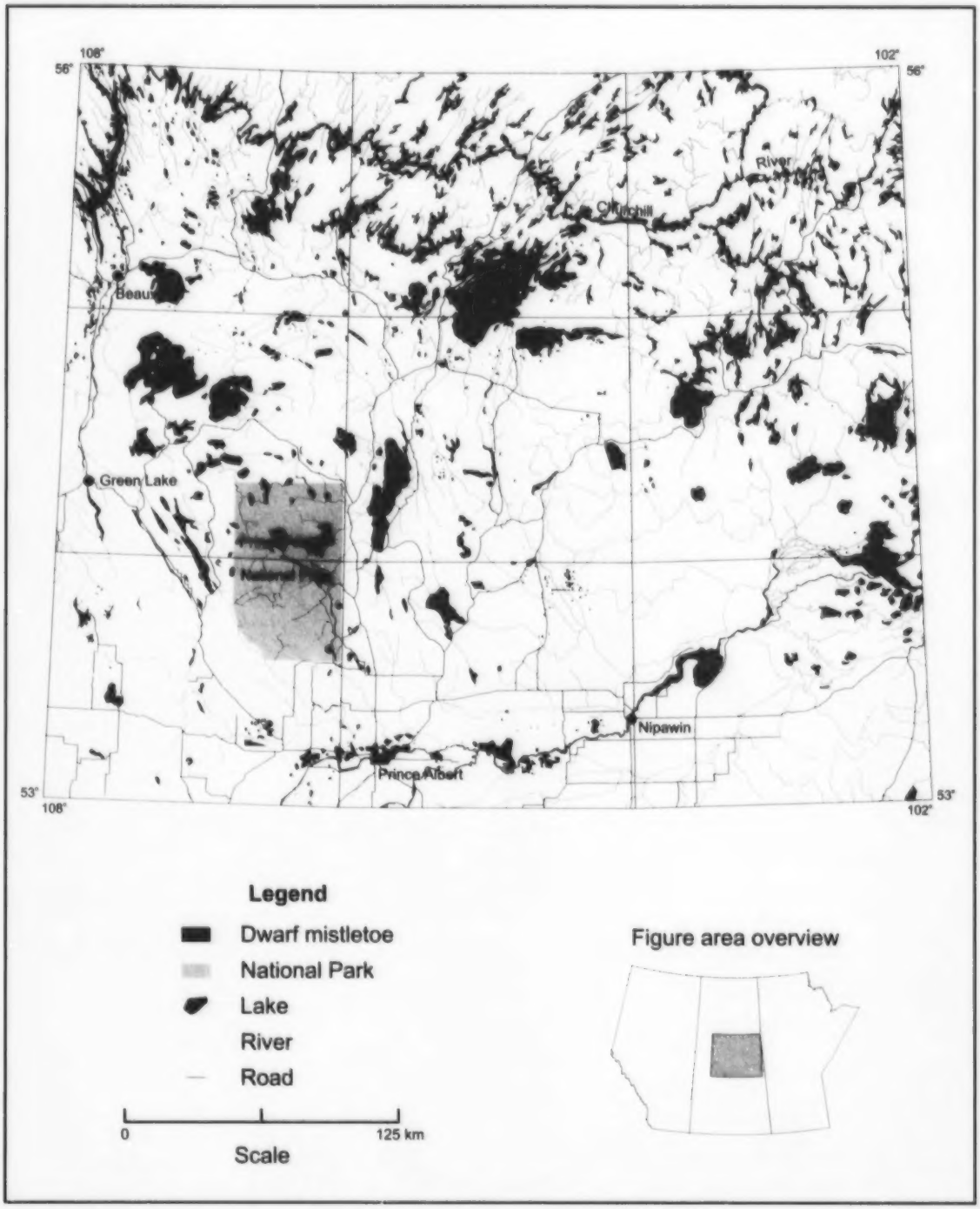

Figure 12. Areas of pine forests severely diseased by dwarf mistletoe in central Saskatchewan bounded by lat. 53°N to lat. 56°N and long. 102°W to long. 108°W. Severely diseased areas are defined as infested areas containing mistletoe-caused tree and branch mortality or trees with many green brooms. Please note: small polygons (<35 ha in size) are not represented on these figures, but they are represented on the digital coverage.

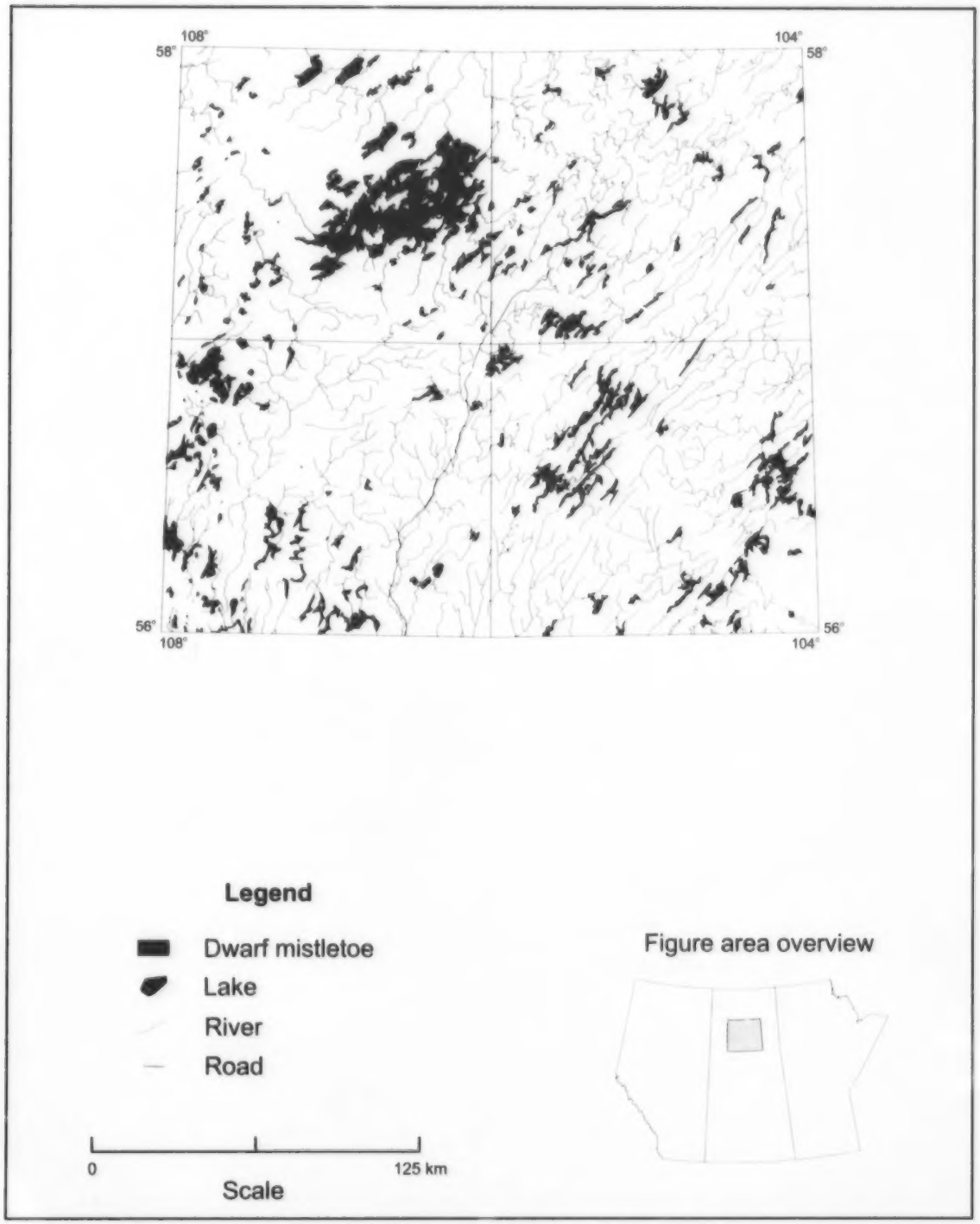

Figure 13. Areas of pine forests severely diseased by dwarf mistletoe in north-central Saskatchewan bounded by lat. 56°N to lat. 58°N and long. 104°W to long. 108°W. Severely diseased areas are defined as infested areas containing mistletoe-caused tree and branch mortality or trees with many green brooms.

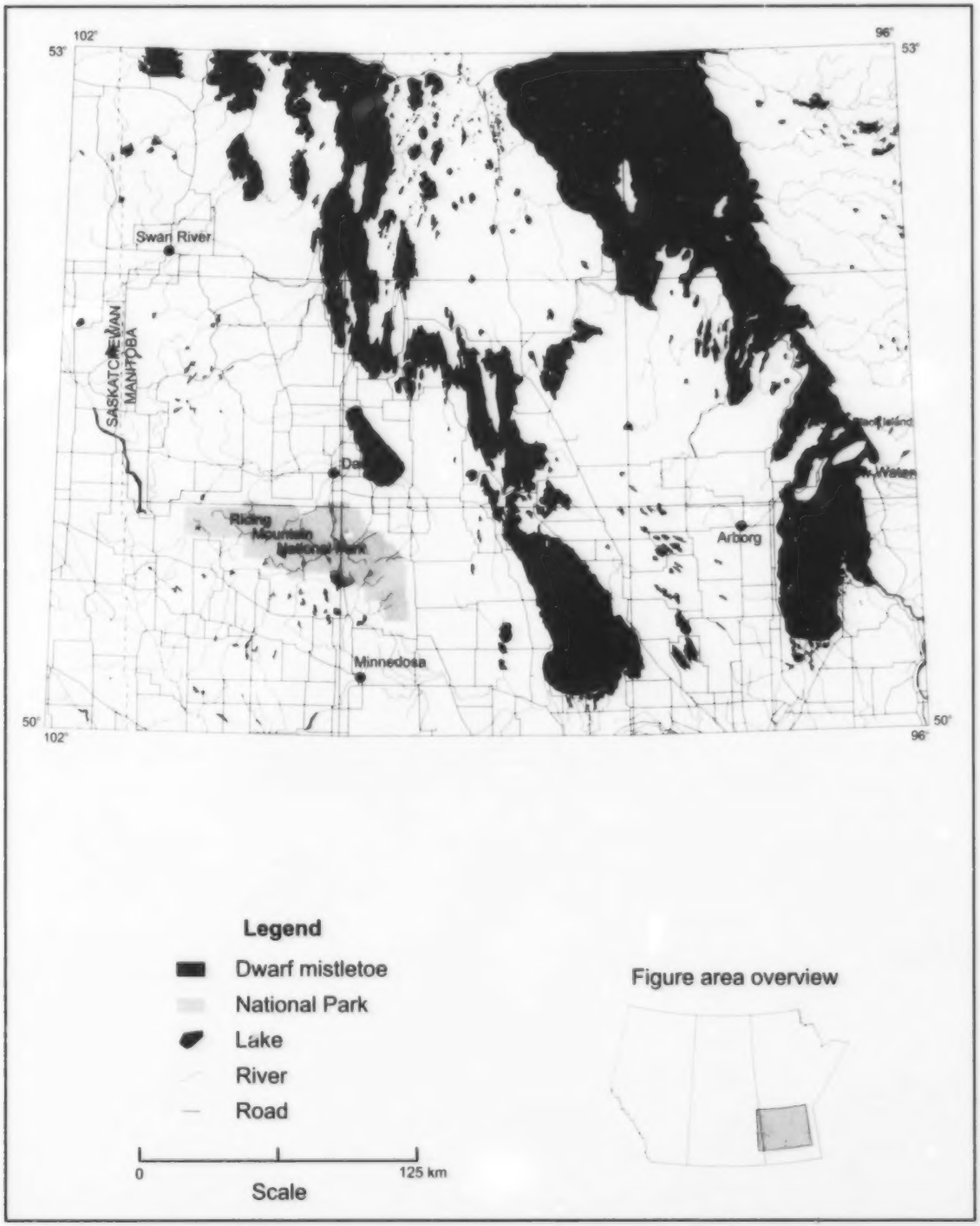

Figure 14. Areas of pine forests severely diseased by dwarf mistletoe in southern Manitoba and southeastern Saskatchewan bounded by lat. 50°N to lat. 53°N and long. 96°W to long. 102°W. Severely diseased areas are defined as infested areas containing mistletoe-caused tree and branch mortality or trees with many green brooms.

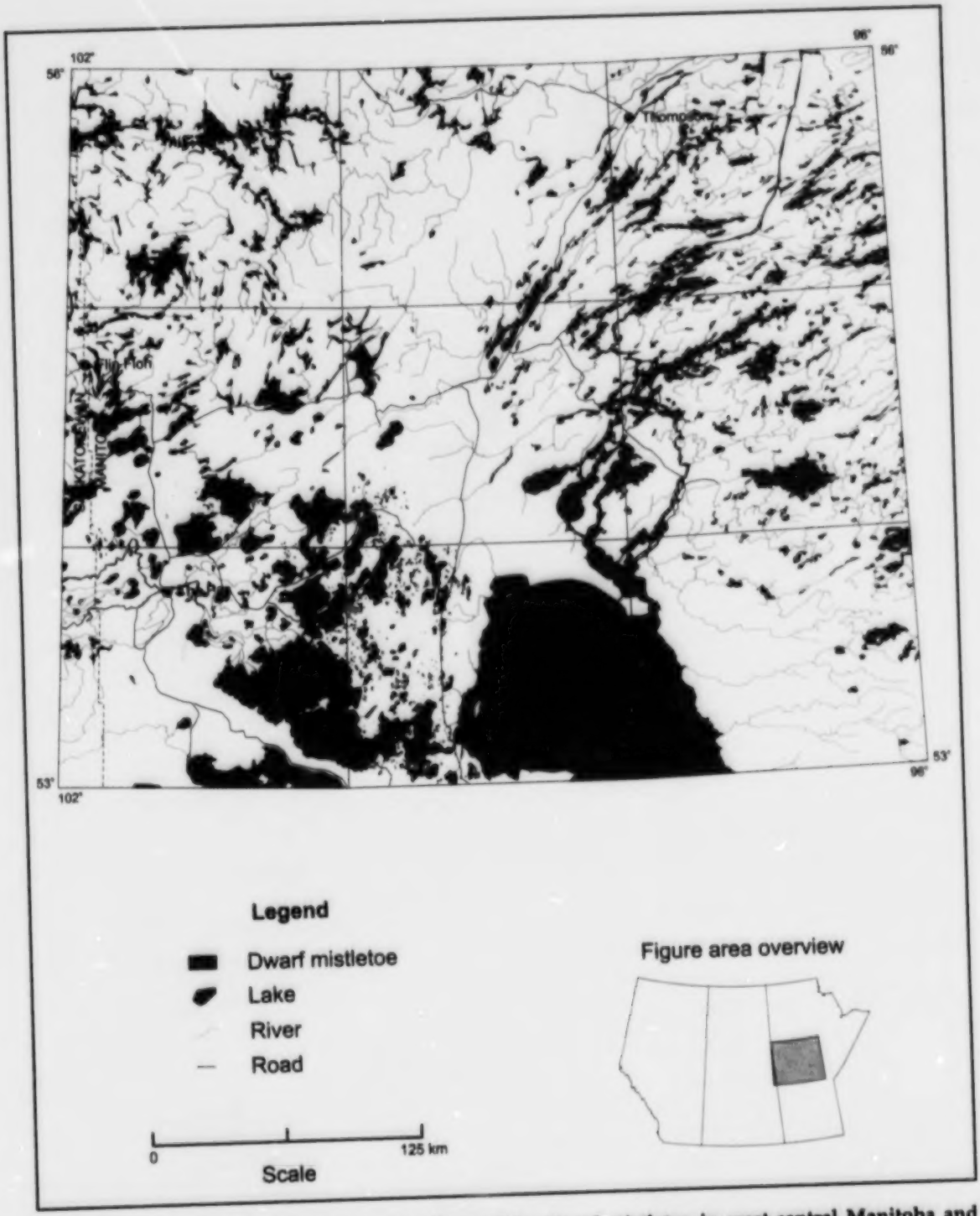

Figure 15. Areas of pine forests severely diseased by dwarf mistletoe in west-central Manitoba and east-central Saskatchewan bounded by lat. 53°N to lat. 56°N and long. 96°W to long. 102°W. Severely diseased areas are defined as infested areas containing mistletoe-caused tree and branch mortality or trees with many green brooms.

Table 1. Area of severely diseased jack and lodgepole pine stands in west-central Canada caused by dwarf mistletoe[a]

Ecozone	Province	Infested area detected[b] ('000 ha)		Infested area with suitable host ('000 ha)	
		Jack pine	Lodgepole pine	Jack pine	Lodgepole pine
Boreal Plains	Alberta	204	41	122	36
	Saskatchewan	156	–[c]	141	–
	Manitoba	69	–	68	–
	Subtotal	429	41	331	36
Boreal Shield	Alberta	67	–	51	–
	Saskatchewan	49	–	49	–
	Manitoba	3	–	3	–
	Subtotal	119	–	103	–
Taiga Shield	Alberta	31	–	15	–
	Saskatchewan	0	–	0	–
	Manitoba	0	–	0	–
	Subtotal	31	–	15	–
Prairies	Alberta	6	1	6	1
	Saskatchewan	0	0[d]	0	–
	Manitoba	0	–	0	–
	Subtotal	6	1	6	1
Montane Cordillera	Alberta	–	43	–	43
	Saskatchewan	–	–	–	–
	Manitoba	–	–	–	–
	Subtotal	–	43	–	43
Total		585	85	455	80

[a] Reported area is based on aerial and ground surveys conducted from 1984 to 1996.

[b] Area determinations differ with different projections. These areas are based on the Lambert Conformal Conic projection using the NAD27 datum within Arc/Info®.

[c] Dashes indicate not applicable.

[d] Less than 200 ha of mistletoe-infested lodgepole pine currently exist in the Saskatchewan portion of the Cypress Hills. These areas were not mapped.

Table 2. Area of pine within the study area[a]

Ecozone	Province	Area ('000 ha)
Boreal Plains	Alberta	3 807
	Saskatchewan	1 424
	Manitoba	679
	Subtotal	5 910
Boreal Shield	Alberta	162
	Saskatchewan	1 821
	Manitoba	3 633
	Subtotal	5 616
Taiga Shield	Alberta	163
	Saskatchewan	6
	Manitoba	140
	Subtotal	309
Taiga Plains	Alberta	55
Prairies	Alberta	148
	Saskatchewan	4
	Manitoba	3
	Subtotal	155
Montane Cordillera	Alberta	808
Total		12 853

[a] Areas are based on the Canada Forest Inventory.

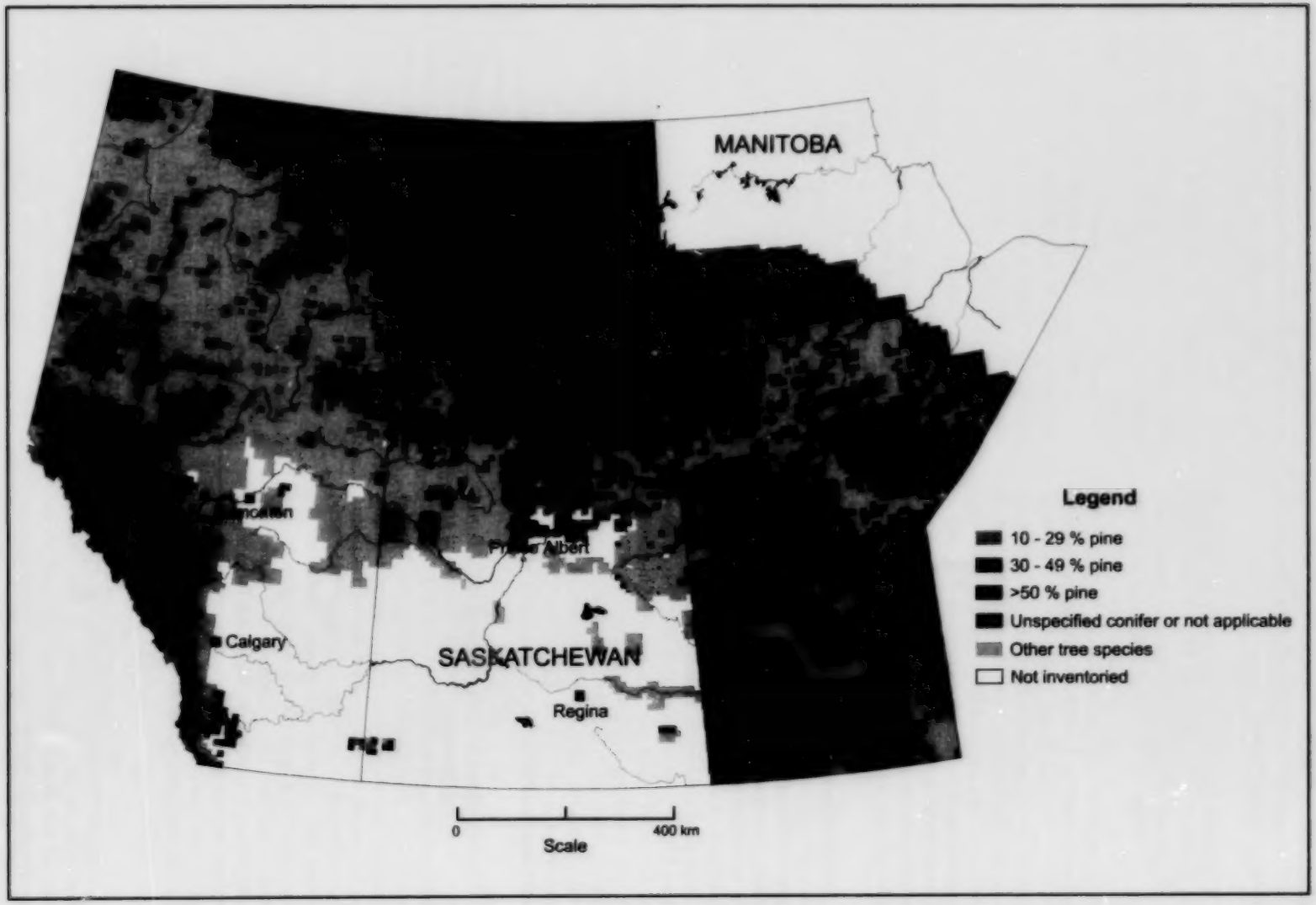

Figure 16. The distribution of pine in west-central Canada. The distribution is based on data collected in the Canada Forest Inventory.

Lambert Conformal Conic projection using the NAD27 datum within Arc/Info®, regardless of the method of determination.

The areas reported in this study differ from those reported by Brandt (1995, 1997). In both of the Brandt studies, areas were determined based on an earlier version of the CanFI inventory, which accounts for some of the discrepancy. For the infested area in Manitoba, Brandt (1995, 1997) based the infested area on that reported by Slivitzky et al. (1991; see also Baker et al. 1992).The authors acquired the original maps from Manitoba Natural Resources. These maps were digitized and when calculations were made of the infested area an error was determined in Slivitzky's original calculation. The areas used in the present study are based on area calculations of the newly digitized Manitoba Natural Resources' maps.

Using the infested areas detected (Table 1), the annual growth and mortality losses in jack pine and lodgepole pine stands were estimated (Tables 3–4). Annual growth and mortality losses for jack pine were estimated at 314 000 m^3 and 1 478 000 m^3, respectively. Annual growth and mortality losses for lodgepole pine were estimated at 486 000 m^3 and 69 000 m^3, respectively. These losses total 2 347 000 m^3yr^{-1} and are not trivial considering that the standing volume of pine in Alberta, Saskatchewan, and Manitoba is approximately 1.1 billion m^3 on the stocked, timber-productive, nonreserved forest lands (Canadian Council of Forest Ministers 1997).

Dwarf mistletoe is most-prevalent in the Boreal Plains ecozone, accounting for 73% of the total area of affected jack pine forests. Another 1% of the affected jack pine forests occur in the Prairies ecozone northeast of Edmonton. Topographically, these ecozones are nearly level to rolling plains. They consist largely of hummucky to kettled glacial moraine and lacustrine deposits underlain by Cretaceous shales. Soils of both ecozones are largely neutral to alkaline. The remaining 26% of the total infested area is in the Boreal Shield and Taiga Shield ecozones. Both of these ecozones are dominated by Precambrian bedrock outcrops and discontinuous morainal deposits. Soils of these ecozones are largely acidic.

Lodgepole pine occurs most frequently in west-central Canada in the foothills of the western portion of the Boreal Plains ecozone and in the Alberta portion of the Montane Cordillera ecozone. The Montane Cordillera and Boreal Plains ecozones account for 51% and 47%, respectively, of the total area of affected lodgepole pine forests, with the remainder in the Cypress Hills of the Prairies ecozone. The Cypress Hills are part of the Cypress Upland ecoregion, which itself is a subdivision of the Prairies ecozone. The ecoregion is an outlier of lodgepole pine and is similar in most respects to ecoregions within the Montane Cordillera ecozone (Ecological Stratification Working Group 1995). Dwarf mistletoe presumably accompanied lodgepole pine when it migrated to the Cypress Hills following the retreat of ice at the end of the Wisconsin glaciation, although long-range dispersal of the mistletoe by birds can not be ruled out (Punter and Gilbert 1989). The Cypress Hills lie about 270 km east of the nearest continuous lodgepole pine stands along the foothills of the Rocky Mountains in southwestern Alberta and about 140 km northwest of the Sweet Grass Hills in Montana, which also have mistletoe-infected lodgepole pine (Thompson and Kuijt 1976). Other pests have migrated this distance in the past. Mountain pine beetle, for example, a serious pest of lodgepole pine over much of its range, was not found in the Cypress Hills until 1979 (Hiratsuka et al. 1980).

A close examination of the mapped infestations in Figures 4–15 reveals that the Hawksworth and Wiens (1972, 1996) information is consistent with the FIDS collections and with this study, with three notable exceptions.

The first major difference is that, other than diseased lodgepole pine stands in the Cypress Hills that straddle the Alberta–Saskatchewan border (Fig. 4), no diseased stands exist in the Prairies ecozone more than a few kilometres south of the North Saskatchewan River (Fig. 9). These infestations are in remnant jack pine stands located on aeolian deposits laid down following the last glaciation.

The second notable difference occurs near Lake Athabasca (Fig. 11). The northern limit of dwarf mistletoe occurs at two locations of the same latitude. One occurs at 59°12'N and 110°38'W, which lies within Alberta a few kilometres north of Lake Athabasca; the second at 59°12'N and 112°23'W, which lies north of the Peace River near its confluence with the Slave River in the Alberta portion of Wood Buffalo National Park. Dwarf mistletoe has not been found in any surveys north of 60°N. As Hawksworth and Wiens (1996) noted, reports by Moody and Cerezke (1985) of mistletoe in jack × lodgepole pine hybrids found in the

Table 3. Estimates of annual growth and mortality losses to jack pine in west-central Canada caused by dwarf mistletoe[a]

Ecozone	Province	Infested area ('000 ha)	Estimated volume on infested area ('000 m^3)[b]	Mortality loss ('000 m^3)[c]	Estimated growth on infested area ('000 m^3)[d]	Growth loss ('000 m^3)[e]
Boreal Plains	Alberta	204	21 624	649	314	126
	Saskatchewan	156	9 360	281	156	62
	Manitoba	69	4 140	124	101	40
Boreal Shield	Alberta	67	7 102	213	103	41
	Saskatchewan	49	2 940	88	49	20
	Manitoba	3	180	5	4	2
Taiga Shield	Alberta	31	3 286	99	48	19
Prairies	Alberta	6	636	19	9	4

[a] Method based on that used by Brandt (1995).

[b] Product of infested area and mean stand volume in infested jack pine stands. The estimated jack pine mean stand volumes are 106, 60, and 60 m^3ha^{-1} in Alberta, Saskatchewan, and Manitoba, respectively.

[c] Product of mortality depletion factor (3%) and estimated volume on infested areas.

[d] Product of infested area and the mean annual increment. Estimated mean annual increments are 1.54, 1.00, and 1.47 $m^3ha^{-1}yr^{-1}$ in Alberta, Saskatchewan, and Manitoba, respectively.

[e] Product of growth loss depletion factor (40%) and estimated growth on infested area.

Table 4. Estimates of annual growth and mortality losses to lodgepole pine in west-central Canada caused by dwarf mistletoe[a]

Ecozone	Province	Infested area ('000 ha)	Estimated volume on infested area ('000 m^3)[b]	Mortality loss ('000 m^3)[c]	Estimated growth on infested area ('000 m^3)[d]	Growth loss ('000 m^3)[e]
Boreal Plains	Alberta	41	9 758	234	87	33
Prairies	Alberta	1	238	6	2	1
Montane Cordillera	Alberta	43	10 234	246	92	35

[a] Method based on that used by Brandt (1995).

[b] Product of infested area and mean stand volume in infested lodgepole pine stands. The estimated lodgepole pine mean stand volume is 238 m^3ha^{-1}.

[c] Product of mortality depletion factor (2.4%) and estimated volume on infested areas.

[d] Product of infested area and the mean annual increment. Estimated mean annual increment is 2.13 $m^3ha^{-1}yr^{-1}$.

[e] Product of growth loss depletion factor (38%) and estimated growth on infested area.

Northwest Territories (i.e., north of 60°N) were unsubstantiated. Subsequent investigation revealed that the parasite was not the causal agent involved in brooming of branches in these hybrids.[1] In Saskatchewan, no mistletoe has been observed on the north side of Lake Athabasca. The northern limit of dwarf mistletoe in Saskatchewan occurs on the south shore of Lake Athabasca at 59°02'N and 109°28'W (Fig. 2).

The third difference occurs east of Lake Winnipeg at dwarf mistletoe's easternly limit (Fig. 14). The extant distribution extends to the southeastern shore of Lake Winnipeg near Belair. Collections were made in 1967 and 1968 near Hollow Water on the eastern shore of Lake Winnipeg about 65 km north of Belair and on Black Island just west of Hollow Water (Figs. 2, 14). These infected stands were small and isolated; recent surveys failed to relocate infested jack pine trees at Hollow Water. The most easternly extent of mistletoe in Manitoba was at Wallace Lake (51°00'N and 95°22'W). (Reported coordinates for Wallace Lake of 49°50'N and 95°30'W [Hawksworth and Wiens 1996] are likely an error). This infestation was eliminated by fire in 1987. The most southernly extent, which was removed by logging in the early 1980s, was in Agassiz Provincial Forest (50°10'N and 96°10'W).

Dwarf mistletoe is scattered throughout its range across Manitoba, Saskatchewan, and eastern Alberta, where it overlaps with the range of jack pine in the Boreal Plains ecozone. This contrasts with the discrete, outlier infestations of mistletoe in west-central Alberta, where its range overlaps the range of lodgepole pine and jack × lodgepole pine hybrids. Hybrids of pine occur near Whitecourt and Grande Prairie (Fig. 7) and north of Peace River (Fig. 8) on inactive, stable sand dunes formed following the last glaciation. Northeast of Whitecourt near the Athabasca River (Fig. 7) and south of High Level near the Peace River (Fig. 8), infested jack pine stands occur on inactive dunes as well. Lodgepole pine on the Swan Hills north of Whitecourt, the Clear Hills and the Saddle Hills north of Grande Prairie, and south of Grande Prairie to Hinton are generally free of the mistletoe, except for several small areas about 70 km northwest of Hinton and just north of Jasper National Park (Fig. 7). Other outlying areas of lodgepole pine on the Caribou Mountains, Birch Mountains, and Thickwood Hills are all free of the parasite.

The factors affecting the distribution of dwarf mistletoe are uncertain. Edaphic factors may have played a role. Dowding (1929) noted that mistletoe was more prevalent and severe in jack pine stands on dry, inactive sand dunes than in jack pine stands on the adjacent low-lying areas. Jameson (1961) noted that mistletoe-infected jack pine in Saskatchewan occurred on two of the driest and poorest quality sites. Growth and mortality losses in infected lodgepole pine were higher on dry sites when compared to a single moist site (Baranyay and Safranyik 1970). The work of Daubenmire (1961) also supports these findings. Western dwarf mistletoe (*A. campylopodum* Engelm.) on ponderosa pine (*Pinus ponderosa* P. Laws. ex C. Laws.) was associated with two out of seven recognized plant community types; these community types were the driest of the seven.

Forest fire undoubtably has played a role. Baranyay (1970) indicated that mistletoe on lodgepole pine was more widespread in the upper foothills of the eastern slopes of the Rocky Mountains than the lower foothills. He hypothesized that because stand-destroying fires were less prevalent in the upper foothills, presumably due to topography, mistletoe quickly reinfected regenerating pine from the infested residual trees that survived the fire. Dowding (1929) reached a similar conclusion for mistletoe on inactive sand dunes in Alberta. In addition to the intensity of fire, fire frequency has also been implicated as a factor in the distribution of the parasite. Taylor (1969) and Zimmerman and Laven (1984) observed that as the frequency of fires decreased, the percentage of trees affected by mistletoe increased.

Climate plays a role in dwarf mistletoe's distribution, but again, the extent to which it is a factor is not well-studied. Temperatures lower than –39°C were found to kill the mistletoe in British Columbia (Smith and Wass 1979). Gilbert and Punter (1991) found pollen of dwarf mistletoe susceptible to low temperature; pollen collected a few days following a spring frost had reduced germinability. Fall frosts also damage the fruit of dwarf mistletoe (Baranyay and Smith 1974). Exposure to a temperature of

[1] Y. Hiratsuka, 1996, Canadian Forest Service, Northern Forestry Centre, Edmonton, Alberta. Personal communication.

–3.9°C for 2.3 h causes permanent damage to the fruits.

The distribution of dwarf mistletoe in west-central Canada raises several interesting questions. Extensive areas of the Northwest Territories, north-eastern Saskatchewan, and northern Manitoba have suitable hosts. Why are these areas free of the disease? What factors affect the distribution of this parasitic plant? At the boundary between the Boreal Plains and Boreal Shield ecozones, do edaphic factors control the vulnerability of jack pine stands to the parasite, or do differences in fire frequencies influence the parasite's distribution between infested areas and those areas free of the parasite? The role of climatic factors also need to be ascertained. Where jack pine and jack × lodgepole pine hybrids occur in Alberta, are jack pine and hybrid pine stands more susceptible to infection by the mistletoe or are edaphic factors on the sand dunes affecting the vulnerability of the host to the pathogen? Obviously, further research is required to answer these questions. The coverage data collected here should assist researchers in their work on this interesting and very damaging parasitic plant.

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REFERENCES

Baker, F.A.; Slivitsky, M.; Knowles, K. 1992. Impact of dwarf mistletoe on jack pine forests in Manitoba. Plant Dis. 76:1256–1259.

Baranyay, J.A. 1970. Lodgepole pine dwarf mistletoe in Alberta. Dep. Fish. For., Can. For. Serv., Ottawa, Ontario. Publ. 1286.

Baranyay, J.A.; Safranyik, L. 1970. Effect of dwarf mistletoe on growth and mortality of lodgepole pine in Alberta. Dep. Fish. For., Can. For. Serv., Ottawa, Ontario. Publ. 1285.

Baranyay, J.A.; Smith, R.B. 1972. Dwarf mistletoes in British Columbia and recommendations for their control. Environ. Can., Can. For. Serv., Pac. For. Res. Cent., Victoria, British Columbia. Inf. Rep. BC-X-72.

Baranyay, J.A.; Smith, R.B. 1974. Low temperature damage to dwarf mistletoe fruit. Can. J. For. Res. 4:361–365.

Barlow, B.A. 1964. Classification of the Loranthaceae and Viscaceae. Proc. Linn. Soc., New South Wales 89:268–272.

Brandt, J.P. 1995. Forest insect- and disease-caused impacts to timber resources of west-central Canada: 1988–92. Nat. Resour. Can., Can. For. Serv., Northwest Reg., North. For. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-341.

Brandt, J.P. 1997. Forest health monitoring in west-central Canada in 1996. Nat. Resour. Can., Can. For. Serv., North. For. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-351.

Canadian Council of Forest Ministers. 1997. Compendium of Canadian forestry statistics 1996. National Forestry Database. Can. Counc. For. Minist., Ottawa, Ontario.

Daubenmire, R. 1961. Vegetative indicators of rate of height growth in ponderosa pine. For. Sci. 7:24–34.

Dooling, O.J. 1978. Survey methods to determine the distribution and intensity of dwarf mistletoes. Pages 36–44 *in* R.F. Scharpf and J.R. Parmeter Jr., tech. coord. Proceedings of the symposium on dwarf mistletoe control through forest management, April 11–13, 1978, Berkeley, California. U.S.

Dep. Agric., For. Serv., Pac. Southwest For. Range Exp. Stn., Berkeley, California. Gen. Tech. Rep. PSW-31.

Dowding, E.S. 1929. The vegetation of Alberta. III. The sandhill areas of central Alberta with particular reference to the ecology of *Arceuthobium americanum* Nutt. J. Ecol. 17: 82–105.

Ecological Stratification Working Group. 1995. A national ecological framework for Canada. Agric. Agri-Food Can., Res. Branch, Cent. Land Biol. Resour. Res., and Environ. Can., Ottawa, Ontario. (Report and national map at 1:7 500 000 scale.)

Environmental Systems Research Institute, Inc. 1992. Understanding GIS. The Arc/Info method. Environ. Syst. Res. Inst., Inc., Redlands, California.

Gilbert, J.; Punter, D. 1990. Release and dispersal of pollen from dwarf mistletoe on jack pine in Manitoba in relation to microclimate. Can. J. For. Res. 20:267–273.

Gilbert, J.; Punter, D. 1991. Germination of pollen of the dwarf mistletoe *Arceuthobium americanum*. Can. J. Bot. 69:685–688.

Gill, L.S. 1935. *Arceuthobium* in the United States. Conn. Acad. Arts Sci., New Haven, Connecticut. Trans. 32:111–245.

Hawksworth, F.G.; Wiens, D. 1972. Biology and classification of dwarf mistletoes (*Arceuthobium*). U.S. Dep. Agric., For. Serv., Washington, D.C. Agric. Handb. 401.

Hawksworth, F.G.; Wiens, D. 1996. Dwarf mistletoes: biology, pathology, and systematics. U.S. Dep. Agric., For. Serv., Washington, D.C Agric. Handb. 709.

Hiratsuka, Y.; Cerezke, H.F.; Petty, J. 1980. Forest insect and disease conditions in Alberta, Saskatchewan, Manitoba, and the Northwest Territories in 1979 and predictions for 1980. Environ. Can., Can. For. Serv., North. For. Res. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-225.

Jameson, J.S. 1961. Observations on factors influencing jack reproduction in Saskatchewan. Can. Dep. For., For. Res. Div., Ottawa, Ontario. Tech. Note 97.

Lowe, J.J.; Power, K.; Gray, S.L. 1994. Canada's forest inventory 1991. Nat. Resour. Can., Can. For. Serv., Petawawa Nat. For. Inst., Chalk River, Ontario. Inf. Rep. PI-X-115.

Merrill, L.M.; Hawksworth, F.G.; Johnson, D.W. 1985. Evaluation of a roadside survey procedure for dwarf mistletoe on ponderosa pine in Colorado. Plant Dis. 69:572–573.

Moody, B.H.; Cerezke, H.F. 1985. Forest insect and disease conditions in Alberta, Saskatchewan, Manitoba, and the Northwest Territories in 1984 and predictions for 1985. Can. For. Serv., North. For. Res. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-269.

Muir, J.A.; Robins, J.K. 1973. Detection of dwarf mistletoe of jack pine on aerial photographs. Plant Dis. Rep. 57:951–954.

Myren, D.T.; Gross, H.L. 1977. Distribution of organisms causing important forest tree diseases in Ontario based on collections recorded by the Forest Insect and Disease Survey Unit. Dep. Fish. For., Can. For. Serv., Great Lakes For. Res. Cent., Sault Ste. Marie, Ontario. Rep. O-X-262.

Punter, D.; Gilbert, J. 1989. Animal vectors of *Arceuthobium americanum* seed in Manitoba. Can. J. For. Res. 19:865–869.

Robins, J.K. 1972. Dwarf mistletoe aerial surveying method: results of preliminary trials in the Athabasca Forest, Alberta, March 1972. Dep. Environ., Can. For. Serv., North. For. Res. Cent., Edmonton, Alberta. Misc. Rep. NOR-Y-10.

Sippell, W.L.; Rose, A.H.; Gross, H.L. 1970. Ontario region. Pages 52–71 *in* Annual report of the Forest Insect and Disease Survey, 1969. Dep. Fish. For., Can. For. Serv., Ottawa, Ontario.

Sippell, W.L.; Gross, H.L.; Rose, A.H. 1971. Ontario region. Pages 49–66 *in* Annual report of the Forest Insect and Disease Survey, 1970. Dep. Fish. For., Can. For. Serv., Ottawa, Ontario.

Slivitzky, M.; Knowles, K.; Baker, F.A. 1991. Impact of dwarf mistletoe on Manitoba jack pine forests. Manitoba Nat. Resour., For. Branch., For. Prot., Winnipeg, Manitoba.

Smith, R.B.; Wass, E.F. 1979. Infection trials with three dwarf mistletoe species within and beyond their known ranges in British Columbia. Can. J. Plant Path. 1:47–57.

Taylor, D.L. 1969. Biotic succession of lodgepole pine forests of fire origin in Yellowstone National Park. Univ. Wyoming, Univ. Wyoming, Laramie, Wyoming. Ph.D. thesis.

Thompson, L.S.; Kuijt, J. 1976. Montane and subalpine plants of the Sweetgrass Hills, Montana, and their relation to early postglacialenvironments of the northern Great Plains. Can. Field-Nat. 90:432–448.

Zimmerman, G.T.; Laven, R.D. 1984. Ecological interrelationships of dwarf mistletoe and fire in lodgepole pine forests. Pages 123–131 *in* F.G. Hawksworth and R.F Scharpf, tech. coord. Biology of dwarf mistletoes: proceedings of the symposium, August 8, 1984, Colorado State University. U.S. Dep. Agric., For. Serv., Rocky Mt. For. Range Exp. Stn., Fort Collins, Colorado. Gen. Tech. Rep. RM-111.

APPENDIX 1
Lambert Conformal Conic Projection Parameters

Projection:	Lambert
Units:	Metres
Datum:	NAD27
First standard parallel:	49 00 00
Second standard parallel:	77 00 00
Central meridian:	−96 00 00
Latitude of projection origin:	00 00 00
False easting (m):	0
False northing (m):	0